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APPLICANT:	Roger BOEN et al.
SERIAL NO.:	10/517,968 CONFIRMATION NO.: 1948
FILING DATE:	December 13, 2004
TITLE:	ELECTROMAGNETIC DEVICE FOR FUSION AND INTERFACIAL AGITATION OF DIPHASE SYSTEMS, PARTICULARLY FOR THE ACCELERATION OF METALLURGIC OR PYROCHEMICAL PROCESSES
EXAMINER:	Not Yet Assigned
ART UNIT:	2831

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Date: 3-14-06 Name: Kathleen K. Muto

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REQUEST FOR REFUND OF FEES

Applicants respectfully request that the United States Patent and Trademark Office issue a refund in the amount of $360.00 to: **THELEN REID & PRIEST LLP Deposit Account No. 50-1698**, which was charged in error by the Patent and Trademark Office for code 1616, multiple dependent claims, for $360.00. Enclosed are courtesy copies of the original French Application showing the changes to be made and which were made in the English translation of the Application filed on May 2, 2005. The English version shows that all multiple dependent claims were amended to non-multiple dependent claims, therefore, eliminating fees for multiple dependent claims. Also enclosed are the fee transmittal, copies of checks for payment of fees, and the Patent and Trademark Office Deposit Account Statement showing the erroneous charge of $360.00 made on June 9, 2005.

Adjustment date: 09/22/2006 THOLLAND
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Please contact Applicants' attorneys at the address, telephone or facsimile number below if there are any matters whose resolution can be expedited thereby.

Respectfully submitted,

THELEN REID & PRIEST LLP

Dated: 3/14/06

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TRAITE DE COOPERATION EN MATIERE DE BREVETS

Expéditeur : L'ADMINISTRATION CHARGEE DE L'EXAMEN PRELIMINAIRE INTERNATIONAL

PCT

Destinataire :

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FRANCE

NOTIFICATION DE TRANSMISSION DU RAPPORT D'EXAMEN PRELIMINAIRE INTERNATIONAL

(règle 71.1 du PCT)

Date d'expédition *(jour/mois/année)*	02.09.2004
Référence du dossier du déposant ou du mandataire: B14042.3 PV	**NOTIFICATION IMPORTANTE**

Demande internationale No.	Date du dépôt international *(jour/mois/année)*	Date de priorité *(jour/mois/année)*
PCT/FR 03/01742	11.06.2003	13.06.2002

Déposant: COMMISSARIAT A L'ENERGIE ATOMIQUE et al.

1. Il est notifié au déposant que l'administration chargée de l'examen préliminaire international a établi le rapport d'examen préliminaire international pour la demande internationale et le lui transmet ci-joint, accompagné, le cas échéant, de ces annexes.

2. Une copie du présent rapport et, le cas échéant, de ses annexes est transmise au Bureau international pour communication à tous les offices élus.

3. Si tel ou tel office élu l'exige, le Bureau international établira une traduction en langue anglaise du rapport (à l'exclusion des annexes de celui-ci) et la transmettra aux offices intéressés.

4. **NOTIFICATION IMPORTANTE**

Pour aborder la phase nationale auprès de chaque office élu, le déposant doit accomplir certains actes (dépôt de traduction et paiement des taxes nationales) dans le délai de 30 mois à compter de la date de priorité (ou plus tard pour ce qui concerne certains offices) (article 39.1) (voir aussi le rappel envoyé par le Bureau international dans le formulaire PCT/IB/301).

Losrqu'une traduction de la demande internationale doit être remise à un office élu, elle doit comporter la traduction de toute annexe du rapport d'examen préliminaire international. Il appartient au déposant d'établir la traduction en question et de la remettre directement à chaque office élu intéressé.

Pour plus de précisions en ce qui concerne les délais applicables et les exigences des offices élus, voir le Volume II du Guide du déposant du PCT.

Il est signalé au déposant que l'article 33(5) stipule que les critères de nouveauté, d'activité inventive et d'application industrielle tels que définis à l'article 33(2) à (4) ne servent qu'aux fins de l'examen préliminaire international et que "tout État contractant peut appliquer des critères additionnels ou différents afin de décider si, dans cet État, l'invention est brevetable ou non" (voir également l'article 27(5)). De tels critères additionnels peuvent par exemple avoir rapport à des exceptions à la brevetabilité ainsi qu'à des exigences concernant l'exposé suffisant de l'invention, la clarté des revendications et leur fondement sur la description.

Nom et adresse postale de l'adminstration chargée de l'examen préliminaire international	Fonctionnaire autorisé
Office européen des brevets D-80298 Munich Tél. +49 89 2399 - 0 Tx: 523656 epmu d	Nordkvist, L Tel. +49 89 2399-7034

TRAITE DE COOPERATION EN MATIERE DE BREVETS

PCT

RAPPORT D'EXAMEN PRELIMINAIRE INTERNATIONAL

(article 36 et règle 70 du PCT)

Référence du dossier du déposant ou du mandataire	**POUR SUITE A DONNER** voir la notification de transmission du rapport d'examen préliminaire international (formulaire PCT/IPEA/416)	
Demande internationale No. PCT/FR 03/01742	Date du dépôt international *(jour/mois/année)* 11.06.2003	Date de priorité *(jour/mois/année)* 13.06.2002
Classification internationale des brevets (CIB) ou à la fois classification nationale et CIB B01F13/08		
Déposant COMMISSARIAT A L'ENERGIE ATOMIQUE et al.		

1. Le présent rapport d'examen préliminaire international, établi par l'administaration chargée de l'examen préliminaire international, est transmis au déposant conformément à l'article 36.

2. Ce RAPPORT comprend 4 feuilles, y compris la présente feuille de couverture.

   ☒ Il est accompagné d'ANNEXES, c'est-à-dire de feuilles de la description, des revendications ou des dessins qui ont été modifiées et qui servent de base au présent rapport ou de feuilles contenant des rectifications faites auprès de l'administration chargée de l'examen préliminaire international (voir la règle 70.16 et l'instruction 607 des Instructions administratives du PCT).

   Ces annexes comprennent 3 feuilles.

3. Le présent rapport contient des indications et les pages correspondantes relatives aux points suivants :

   - I ☒ Base de l'opinion
   - II ☐ Priorité
   - III ☐ Absence de formulation d'opinion quant à la nouveauté, l'activité inventive et la possibilité d'application industrielle
   - IV ☐ Absence d'unité de l'invention
   - V ☒ Déclaration motivée selon la règle 66.2(a)(ii) quant à la nouveauté, l'activité inventive et la possibilité d'application industrielle; citations et explications à l'appui de cette déclaration
   - VI ☐ Certains documents cités
   - VII ☐ Irrégularités dans la demande internationale
   - VIII ☐ Observations relatives à la demande internationale

Date de présentation de la demande d'examen préliminaire internationale	Date d'achèvement du présent rapport
07.01.2004	02.09.2004
Nom et adresse postale de l'adminstration chargée de l'examen préliminaire international Office européen des brevets D-80298 Munich Tél. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Fonctionnaire autorisé Muller, G N° de téléphone +49 89 2399-2331

RAPPORT D'EXAMEN PRÉLIMINAIRE INTERNATIONAL

Demande internationale n° PCT/FR 03/01742

I. Base du rapport

1. En ce qui concerne les **éléments** de la demande internationale *(les feuilles de remplacement qui ont été remises à l'office récepteur en réponse à une invitation faite conformément à l'article 14 sont considérées, dans le présent rapport, comme "initialement déposées" et ne sont pas jointes en annexe au rapport puisqu'elles ne contiennent pas de modifications (règles 70.16 et 70.17))* :

Description, Pages

1-16 telles qu'initialement déposées

Revendications, No.

1-12 reçue(s) le 16.08.2004 avec lettre du 10.08.2004

Dessins, Feuilles

1/2-2/2 telles qu'initialement déposées

2. En ce qui concerne la **langue**, tous les éléments indiqués ci-dessus étaient à la disposition de l'administration ou lui ont été remis dans la langue dans laquelle la demande internationale a été déposée, sauf indication contraire donnée sous ce point.

   Ces éléments étaient à la disposition de l'administration ou lui ont été remis dans la langue suivante: ,qui est:

   ☐ la langue d'une traduction remise aux fins de la recherche internationale (selon la règle 23.1(b)).

   ☐ la langue de publication de la demande internationale (selon la règle 48.3(b)).

   ☐ la langue de la traduction remise aux fins de l'examen préliminaire internationale (selon la règle 55.2 ou 55.3).

3. En ce qui concerne les **séquences de nucléotides ou d'acide aminés**divulguées dans la demande internationale (le cas échéant), l'examen préliminaire internationale a été effectué sur la base du listage des séquences :

   ☐ contenu dans la demande internationale, sous forme écrite.

   ☐ déposé avec la demande internationale, sous forme déchiffrable par ordinateur.

   ☐ remis ultérieurement à l'administration, sous forme écrite.

   ☐ remis ultérieurement à l'administration, sous forme déchiffrable par ordinateur.

   ☐ La déclaration, selon laquelle le listage des séquences par écrit et fourni ultérieurement ne va pas au-delà de la divulgation faite dans la demande telle que déposée, a été fournie.

   ☐ La déclaration, selon laquelle les informations enregistrées sous déchiffrable par ordinateur sont identiques à celles du listages des séquences Présenté par écrit, a été fournie.

4. Les modifications ont entraîné l'annulation :

   ☐ de la description, pages :

   ☐ des revendications, nos :

   ☐ des dessins, feuilles :

5. ☐ Le présent rapport a été formulé abstraction faite (de certaines) des modifications, qui ont été considérées comme allant au-delà de l'exposé de l'invention tel qu'il a été déposé, comme il est indiqué ci-après (règle 70.2(c)) :

   (Toute feuille de remplacement comportant des modifications de cette nature doit être indiquée au point 1 et annexée au présent rapport.)

6. Observations complémentaires, le cas échéant :

V. Déclaration motivée selon l'article 35(2) quant à la nouveauté, l'activité inventive et la possibilité d'application industrielle; citations et explications à l'appui de cette déclaration

1. Déclaration

Nouveauté	Oui:	Revendications	1-12
	Non:	Revendications	
Activité inventive	Oui:	Revendications	1-12
	Non:	Revendications	
Possibilité d'application industrielle	Oui:	Revendications	1-12
	Non:	Revendications	

2. Citations et explications

   voir feuille séparée

Concernant le point V

Déclaration motivée quant à la nouveauté, l'activité inventive et la possibilité d'application industrielle; citations et explications à l'appui de cette déclaration

Il est fait référence aux documents suivants:

D1: EP-A-0 286 934 (ASEA BROWN BOVERI) 19 octobre 1988 (1988-10-19)

D2: US-A-4 778 518 (GRIMFJAERD GOERAN ET AL) 18 octobre 1988 (1988-10-18)

Le document D1, qui est considéré comme étant l'état de la technique le plus proche de l'objet de la revendication 1, décrit un dispositif de fusion et d'agitation d'un système biphasique. Ce dispositif comprenant un moyen de chauffage par arc électrique et un moyen de brassage par induction électromagnétique.

Par conséquent, l'objet de la revendication 1 diffère de ce dispositif connu en ce que: à la fois le chauffage et le brassage sont assurés simultanément par le même inducteur.

L'objet de la revendication 1 est donc nouveau (article 33(2) PCT).

Le problème que la présente invention se propose de résoudre peut donc être considéré comme fournir un dispositif de chauffage et de brassage d'un système biphasique (métal et sel fondu) simplifié.

La solution de ce problème proposée dans la revendication 1 de la présente demande est considérée comme impliquant une activité inventive (article 33(3) PCT), et ce pour les raisons suivantes :

L'utilisation dans l'inducteur d'un courant haute fréquence pour la fusion, modulé par un courant basse fréquence pour l'agitation, n'est suggéré ou rendu évident par aucun état de la technique disponible.

Les revendications 2-12 dépendent de la revendication 1 et satisfont donc également, en tant que telles, aux conditions requises par le PCT en ce qui concerne la nouveauté et l'activité inventive.

REVENDICATIONS

1. Dispositif de fusion et d'agitation interfaciale d'un système diphasique, ce dernier comprenant des première et deuxième phases immiscibles, séparées par une interface, ce dispositif comprenant :

- un creuset (2, 28), destiné à contenir le système diphasique, et
- des moyens de fusion et d'agitation prévus pour la fusion des première et deuxième phases et l'agitation de l'interface de celles-ci,

ce dispositif étant caractérisé en ce que les moyens de fusion et d'agitation comprennent :

- un inducteur (4) entourant le creuset et
- des moyens (18) d'alimentation de cet inducteur par un courant variable ayant ~~au moins une composante, cette composante étant apte à agiter l'interface des première et deuxième phases.~~

~~2. Dispositif selon la revendication 1, dans lequel le creuset est un creuset froid (2) et le courant variable a~~ des première et deuxième composantes, la première composante ayant une première fréquence et étant apte à faire fondre les première et deuxième phases, la deuxième composante ayant une deuxième fréquence, qui est inférieure à la première fréquence, et étant apte à agiter l'interface des première et deuxième phases.

2. ~~3.~~ Dispositif selon la revendication 1, dans lequel les moyens (18) d'alimentation de l'inducteur sont aptes à fournir un courant alternatif ayant la première fréquence, ce courant alternatif étant modulé par la deuxième fréquence.

3. Dispositif selon la revendication 2, dans lequel les moyens d'alimentation de l'inducteur comprennent

- un condensateur (24) formant, avec l'inducteur (4), un circuit oscillant qui fonctionne à sa propre fréquence de résonance, cette fréquence de résonance formant la première fréquence,

- un générateur à induction (22) prévu pour alimenter ce circuit oscillant, et

- un générateur de fonction (20) prévu pour imposer la modulation à la deuxième fréquence et pour fournir un courant de consigne au générateur à induction.

4. Dispositif selon la revendication 3, dans lequel la puissance du générateur à induction (22) est dans l'intervalle allant de 10 kW à 300 kW.

5. Dispositif selon l'une quelconque des revendications 3 et 4, dans lequel la fréquence de résonance est dans l'intervalle allant de 1 kHz à 20 kHz.

6. Dispositif selon l'une quelconque des revendications 3 à 5, dans lequel la fréquence de la modulation est dans l'intervalle allant de 0,5 Hz à 10 Hz.

7. Dispositif selon l'une quelconque des revendications 1 à 6, dans lequel le creuset est un creuset froid (21).

8. Dispositif selon la revendication 1 à 6, dans lequel le creuset est un creuset chaud (28).

9. Dispositif selon la revendication 1, dans lequel la fréquence de la composante qui est apte à agiter l'interface des première et deuxième phases est choisie suffisamment basse pour que la composante soit en outre apte à agiter la deuxième phase, lorsque

cette dernière est peu électriquement conductrice, cette deuxième phase étant au-dessus de la première phase.

10. Dispositif selon l'une quelconque des revendications 1 à 9, comprenant en outre des moyens (26) de maîtrise des gradients thermiques à l'intérieur des première et deuxième phases.

11. Dispositif selon la revendication 10, dans lequel ces moyens de maîtrise comprennent des écrans ou des suscepteurs (26).

12. Application du dispositif selon l'une quelconque des revendications 1 à 11 à la fusion et l'agitation interfaciale d'un système diphasique dans lequel la première phase (8) est un métal et la deuxième phase (10) est un laitier ou un sel.

ELECTROMAGNETIC DEVICE FOR FUSION AND INTERFACIAL AGITATION OF DIPHASE SYSTEMS, PARTICULARLY FOR THE ACCELERATION OF METALLURGIC OR PYROCHEMICAL PROCESSES

DESCRIPTION

TECHNICAL FIELD

The present invention relates to a fusion and interfacial agitation device for a diphase system.

It particularly applies to the acceleration of metallurgic processes as well as to the acceleration of pyrochemical processes.

STATE OF THE PRIOR ART

Metallurgic elaboration or refining procedures generally implement two immiscible phases between which exchanges of materials take place.

The fusion of phases can be ensured in different ways, for example by Joule effect or by induction.

Agitation of the interface of the two phases uses mechanical or pneumatic methods. This agitation is indispensable to the acceleration of the physico-chemical process so as to attain equilibrium times that are short enough for the procedures to be profitable.

Figure 1 is a schematic and partial view of a known device making it possible to melt a diphase system and to agitate the interface of this system.

This known device comprises a cold crucible 2. Water circulation 3 means enable this crucible 2 to be cooled.

The device in figure 1 also comprises an inductor 4 that surrounds the crucible 2 and that is supplied by a source 6 of high frequency current to create in crucible 2 a high-frequency electromagnetic field.

In the diphase system contained in the crucible this field generates induced currents which dissipate the power by Joule effect and melt the diphase system. The latter is composed of two immiscible phases i.e. a lower phase 8 and a higher phase 10, which are separated by an interface 12.

Lines 14 of figure 1 symbolise the internal mixing of the lower phase 8. This mixture is generated by the induced currents.

The device in figure 1 also comprises mechanical means 16 enabling the interface 12 to be agitated.

One can envisage using the "monofrequency" device of figure 1 with the diphase system whose fusion leads to a lower phase 8 made up of a liquid metal and a higher phase 10 made up of molten salt.

It is possible to melt these phases using the cold crucible 2 (or a hot crucible) but the transfer of chemical species towards the higher phase 10 from the lower phase 8 (which is likely to contain these chemical species) can only be carried out by agitating interface 12 sufficiently.

However, media made up of phases 8 and 10 are likely to have a very high reactivity, preventing the introduction of a third phase in these media and therefore any mechanical or pneumatic agitation of them.

In fact, mechanical (or pneumatic) agitation would lead to inserting a solid (or gas) into these media.

Moreover, where the lower 8 medium is metallic, it turns out that electromagnetic agitation linked to the application of a high frequency is limited to this metallic medium and does not have a sufficient effect at the interface 12 of media 8 and 10.

PRESENTATION OF THE INVENTION

The present invention aims to remedy the preceding drawbacks. It enables:

- fusion of the phases in a cold or hot crucible,
- agitation of the lower phase (which can be a metallic bath),
- agitation of the interface separating the phases and
- agitation of the phase which has only slight conduction choosing the modulation frequency in the lower part of the range.

In the invention, these agitations are obtained without contact with the phases.

In addition, the invention enables the interface to be agitated locally to minimise the transfer barrier effect which constitutes a diffusion underlayer likely to be formed at the interface and to renew the chemical species to be transferred through the interface, between the two phases.

To be precise, the present invention relates to a device for fusion and interfacial agitation of a diphase system, the latter comprising first and second immiscible phases which are separated by an interface, this device comprising:

- a crucible intended to contain the diphase system and
- fusion and agitation means provided for the fusion of the first and second phases and the agitation of their interfaces,

this device being characterised in that the fusion and agitation means include

- an inductor surrounding the crucible and
- means of supplying this inductor by a variable current with at least one component, this component being capable of agitating the interface of the first and second phases.

According to a first particular embodiment of the device according to the invention, the crucible is a cold crucible and the variable current has first and second components, the first component having a first frequency and being capable of melting the first and second phases, the second component having a second frequency, which is lower than the first frequency and

capable of agitating the interface of the first and second phases.

According to a preferred embodiment of this device, the means of supplying the inductor are capable of providing an alternative current with the first frequency, this alternative current being modulated by the second frequency.

The means for supplying the inductor preferably include

- a capacitor forming with the inductor an oscillating circuit which operates at its own resonance frequency, this resonance frequency forming the first frequency,

- an induction generator provided to supply this oscillating circuit and

- a function generator provided to impose modulation at the second frequency and supply a reference current to the induction generator.

The power of the induction generator is preferably in the interval from 10 kW to 300 kW.

The resonance frequency is preferably in the interval from 1 kHz to 20 kHz.

This resonance frequency preferably amounts to approximately 14 kHz.

The modulation frequency is preferably in an interval from 0.5 Hz to 10 Hz.

According to the second mode of realisation specific to the device that is the subject of this invention, the crucible is a hot crucible.

According to a second particular embodiment of the device according to the invention, the frequency

of the component which is capable of agitating the interface of the first and second phases is selected low enough for the component to be also capable of agitating the second phase when the latter is little electrically conductive, this second phase being above the first phase.

The device according to the invention can also comprise means for controlling the thermal gradients inside the first and second phases.

These controlling means can comprise screens or susceptors.

The device according to the invention particularly applies to the fusion and interfacial agitation of a diphase system in which the first phase is a metal and the second phase is a slag or a salt.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be better understood on reading a description of examples of implementation given below, purely for guidance and in no way restrictive, referring to the appended drawings where:

- Figure 1 is a schematic and partial view of a known "monofrequency" device with a cold crucible, mechanically agitated and which has already been described,

- Figure 2 is a schematic and partial view of a "bifrequency" device in accordance with the invention, with a cold crucible, agitated electromagnetically,

- Figure 3 is a diagram of an example of means of supplying electricity to the inductor of the device of figure 2, and

- Figure 4 is a schematic and partial view of a device in accordance with the invention, with a hot crucible agitated electromagnetically.

DETAILED PRESENTATION OF PARTICULAR EMBODIMENTS

A device in accordance with the invention makes it possible to accelerate the chemical exchanges between two immiscible phases heated by induction. This device jointly provides the fusion of the two phases, the mixing of the lower phase which is for example a liquid metal and the agitation of the interface between the phases.

In accordance with the invention, all these functions are provided by the use of a cold crucible supplied with an alternative electrical current with two frequencies, i.e. a high frequency and a low frequency.

This makes it possible, without any contact with the reaction medium,

- to heat and melt the lower phase (metallic phase in the example) thanks to the high frequency component of the inductor current, the heating and the fusion of the higher phase (oxide or saline slag in the example) taking place by conduction and convection,

- to mix the metallic bath thanks to the same high-frequency component and

- to ensure agitation of the interface between the metallic phase and the slag using the current's low frequency component.

Figure 2 is a schematic view of a device in accordance with the invention, enabling fusion of the diphase system by applying a double frequency. In this case, interface 12 is agitated electromagnetically and therefore without contact.

To achieve the internal mixture and the heating in an optimum manner, the high frequency is selected according to the following traditional criterion:

$$0.1 < \delta/Ri < 0.3$$

where Ri represents the inner radius of crucible 2 and δ the electromagnetic of skin depth in liquid metal 8.

The agitation of interface 12 is obtained by a judicious choice of the low frequency component of the inductor current. This is defined from the eigen frequencies of the gravito-capillary waves of the interface as follows:

$$f_b \approx (g/2\pi Ri)^{1/2}$$

where f_b represents the frequency of the low frequency modulation of the inductor current and g the acceleration of gravity.

According to the specific value of this modulation frequency, the wavelength of the deformation of interface 12 can be selected according to the species to be transferred and the state of passivation of this interface 12.

The device of figure 2 includes means 18

for supplying the inductor 4. These means 18 enable a high frequency current to be generated which is modulated by a low frequency.

An example of these means 18 is schematically represented in figure 3 and comprises a function generator 20, an induction generator 22 and a capacitor 24 formed by a battery of elementary capacitors.

The system formed by the inductor 4 and the cold crucible 2 of figure 2 is characterised on figure 3 by a resistor R and an inductance L.

The inductor is mounted in parallel with the capacitors battery 24 and forms with the latter an oscillating circuit.

The inductor generator 22 has a power of 100 kW and supplies this oscillating circuit. The latter works at its own resonance frequency which is approximately 14 kHz.

The modulation is imposed by the function generator 20.

In the example of figure 3 this generator 20 is the kind that is sold by the Metrix company.

The function generator 20 provides a reference current at the imput of the induction generator 22. The latter is mounted in parallel with the capacitors battery 24.

The obtained inductor current has the conventional appearance of a sinusoidal carrier signal which is modulated by another sinusoidal signal, the carrier signal having the oscillating circuit's eigen frequency (high frequency) while the frequency of the

other sinusoidal signal corresponds to the low frequency mentioned above.

Prior studies have been done to characterise the influence of different types of agitation on mass transfers through a metal/liquid interface.

First of all, transfer experiments have been made on a pocket of mercury placed in a solenoid coil fed by an alternative electrical current. According to the frequency of this current, it is possible to create three types of movement in the mercury:

- an inner electromagnetic mixing without surface oscillation (f> 20Hz)
- oscillations of the mercury-electrolyte interface without internal mixing (f < 10 Hz).
- an internal mixing with superimposed surface oscillations which constitute a mixed rate (10 Hz < f < 20 Hz).

The experiments were made with a tank with a diameter of 178 mm and a mercury height of 124 mm.

Exchange ratios were established which were obtained according to the intensity of the speed of the fluid which is proportionate to the intensity of the inductor current and it was found that a frequency f of 14 Hz (mixed rate) gives the highest values of the exchange ratios.

It was possible, from measurements and similarity analyses, to formulate, for exchange ratio k, a semi-empirical law which is valid in case of high speeds and such that:

$$k = a(D_m/d)\ (\rho U^2/(\rho g\gamma)^{1/2})^{3/4} \qquad [1]$$

k: exchange ratio also called mass transfer ratio (m/s)

Dm: ratio of diffusion of the compound in its liquid matrix

d: diameter of the pocket

U: characteristic speed of the bath

ρ: volume mass of the bath

g: acceleration of the gravity

γ: interfacial tension.

a is an empirical ratio characterising the efficiency of the agitation. The values arising from the experiments made with the mercury are as follows:

a of the order of 10^3 for the surface agitation alone,

a of the order of 1.3×10^4 for internal agitation,

a of the order of 2.8×10^4 to 6.0×10^4 for the mixed rate.

The measurements of the mass transfer ratio at the interface according to the different types of agitation have shown that the most effective transfer was obtained in the case of the mixed rate. The transfer gain varies from a factor of 2 to 5 and can be explained by the following:

- The internal mixture is indispensable to renew the chemical species near the interface but it is not enough to break the diffusion barrier.

- The surface waves have the effect of creating local agitation on the interface and reducing the effect of the diffusion barrier. In addition,

specific tests have shown that this type of agitation enables possible passivation layers that disturb all the transfer physical-chemical processes to be broken.

Agitation tests carried out under heat have shown the need to have an overall agitation of the bath as well as of the interface.

A transfer test was carried out at 750 °C between a metallic bath with a zinc base and a fluorated saline phase.

Without interface agitation, a large number of metallic particles are reduced but not transferred. In this case the transfer operation is not carried out and cannot be done within a reasonable time (less than 24h).

With interfacial agitation, the reducible elements are entirely transferred towards the metallic phase. In this case the transfer operation is carried out in a few minutes.

The same observations were made with the use of Al-Cu alloys and $LiF-CaF_2$ salt.

It was also verified that use of an electromagnetic method prevents the inclusion of contamination elements from mechanical agitation systems.

An in-depth study of the physico-chemical phenomena that occur in these diphase environments shows the possibility of seeing appear at the interface passivation layers that induce galvanic phenomena on both sides of the interface.

Therefore elements can be reduced directly inside the salt by electronic transfer, without there

being any transfer of these elements towards the metallic phase. One finds oneself then with a saline phase loaded with reduced metallic species that have not been decanted towards the metallic phase.

Performing interfacial agitation prevents the formation of these passivating layers and enables the saline phase to be totally purified. This highlights the absolute necessity of maintaining an interfacial agitation so as to totally purify one of the two phases.

The characteristic speed U of a liquid steel bath contained in a cold crucible of 60 mm in diameter has been numerically estimated, generating a static dome with a height H of 30mm:

$$U \approx 0.4\ (gH)^{1/2} = 0.22\ m/s.$$

For $\gamma = 1.7$ N/m and $\rho = 7200 kg/m^3$, the semi-empiric relation [1] provides an assessment of the exchange ratio: $k = 9.3 \times 10^{-4}$ m/s.

Thus for a bath height of 60 mm, it is possible to deduct the characteristic time of mass transfer T such that:

$$T = V/(kS) \approx 64\ s$$

where V represents the volume of the bath and S the interface area and a is considered equal to 2.8×10^{-4}.

It is also possible to determine the optimum frequency for the mass transfer. To do this and in view of the preceding arguments interface waves must be energized whose wavelength is close to the capillary length λ such that:

$$\lambda = (\gamma/(\rho g))^{1/2}.$$

λ is equal to 5 mm for liquid steel. It is therefore possible to deduce the modulation frequency f to energize the surface movement:

$$f = (1/(2\pi)) \times (g/\lambda)^{1/2} \approx 7 \text{ Hz}.$$

It is important to emphasize that the present invention, which links a cold crucible and a high frequency modulated by a low frequency is of interest in all alloy making or refining metallurgic activities as well as in advanced pyrochemical extraction and separation procedures.

It effectively displays all the advantages linked to the use of a cold crucible without any mechanical agitation being used.

Thus all the pollution or corrosion problems linked to the use of a mechanical or pneumatic agitation are resolved.

In addition, the geometry, intensity and frequencies of the electromagnetic forces field can be chosen according to the effects sought.

In addition it is possible to add to the device according to the invention that can be seen in figure 2 elements such as screens or susceptors 26 (figure 2), placed so as to better control the thermal gradients inside the metallic bath 8 and the slag 10.

The present invention is not limited to the electromagnetic agitation of a diphase system in a cold crucible.

It also applies to the electromagnetic agitation of a diphase system in a hot crucible.

The later application is schematically illustrated by figure 4 where a hot crucible 28 can be

seen with water circulation means 30 enabling this hot crucible 28 to be cooled.

This crucible is surrounded by a heating electrical resistor which is schematically shown by lines or R and supplied by a current source not shown. This resistor enables crucible 29 to be heated by Joule effect and thus to melt the diphase system (phases 8 and 10) contained in the crucible.

The device in figure 4 also includes an inductor 32 which surrounds crucible 28 and which is supplied by a low frequency current source 34. Thanks to this inductor 32, a low frequency electromagnetic field is created in the crucible enabling the interface to be agitated between the lower phase 8 (for example a metallic phase) and the higher phase 10 (for example a molten salt).

The frequency used is selected in the interval going from 0.5 Hz to 10 Hz.

Instead of providing the crucible 28 with the heating resistor R this crucible can be placed in a susceptor S, for example in graphite, itself placed in the inductor 32 and this inductor 34 can be fed by a dual frequency current source 36 like the means (or source) 18 described above, on one hand in view of heating the crucible 28 by induction (using the highest frequency) so that the latter then heats the diphase system it contains, and on the other hand in view of agitating the interface of the system's two phases (using the lowest frequency).

It is also specified that the upper phase 10 can be agitated, when the latter only conducts a

little electricity, thanks to the low frequency provided by the source 18 or 34 or 36 if this low frequency is selected in a range from 0.5 Hz to 10 Hz.

5

CLAIMS

1. Device for fusion and interfacial agitation of a diphase system, the latter comprising first and second immiscible phases separated by an interface, this device comprising:

- a crucible (2, 28), intended to contain the diphase system and
- fusion and agitation means provided for the fusion of the first and second phases and the agitation of their interface,

this device being characterised in that the fusion and agitation means include:

- an inductor (4) surrounding the crucible and
- means of supplying (18) this inductor by a variable current with at least one component, this component being capable of agitating the interface of the first and second phases.

2. Device according to claim 1, in which the crucible is a cold crucible (2) and the variable current has first and second components, the first component having a first frequency and being capable of melting the first and second phases, the second component having a second frequency which is lower than the first frequency and capable of agitating the interface of the first and second phases.

3. Device according to claim 2, in which the means (18) of supplying the inductor are capable of providing an alternative current with the first frequency, this alternative current being modulated by the second frequency.

4. Device according to claim 3, in which the means of supplying the inductor include

- a capacitor (24) forming, with the inductor (4), an oscillating circuit that operates at its own resonance frequency, this resonance frequency forming the first frequency,

- an induction generator (22) provided to supply this oscillating circuit and

- a function generator (20) provided to impose modulation at the second frequency and to supply a reference current to the induction generator.

5. Device according to claim 4, in which the power of the induction generator (22) is in the interval from 10 kW to 300 kW.

6. Device according to any of claims 4 and 5, in which the resonance frequency is in the interval from 1 kHz to 20 kHz.

7. Device according to any of claims 4 to 6, in which the modulation frequency is in the interval from 0.5 Hz to 10 Hz.

8. Device according to claim 1, in which the crucible is a hot crucible (28).

9. Device according to claim 1, in which the frequency of the component which is capable of agitating the interface of the first and second phases is chosen low enough for the component to also be capable of agitating the second phase, when the latter is little electrically conductive, this second phase being above the first phase.

10. Device according to any of claims 1 to 9, including in addition means (26) for controlling thermal gradients inside the first and second phases.

11. Device according to claim 10, in which these control means comprise screens or susceptors (26).

12. Application of the device according to any of claims 1 to 11 to fusion and interfacial agitation of a diphase system in which the first phase (8) is a metal and the second phase (10) is a slag or a salt.

ABSTRACT

Electromagnetic device for fusion and interfacial agitation of diphase systems, particularly for the acceleration of metallurgic or pyrochemical processes.

This device comprises for example a crucible (2, 28), to contain a diphase system, an inductor (4) surrounding this crucible and means (18) for the supply of the inductor by a current with two components, namely a high frequency component which melts the phases of the system and a low frequency component which agitates the interface (12) of the phases.

Figure 2.

PTO-1390 (Rev. 12-2004)
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TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A SUBMISSION UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER	
034299-611	
U.S. APPLICATION NO. (If known, see 37 CFR 1.5)	
unassigned	

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/FR03/01742	June 11, 2003	June 13, 2002

TITLE OF INVENTION
Electromagnetic Device for Interfacial Melting and Stirring of Diphasic Systems, In Particular for Accelerating Metallurgical of Pyrochemical Processes

APPLICANT(S) FOR DO/EO/US
BOEN, Roger; DESCHANELS, Xavier; LEMORT, Florent, PICCINATO, Rene; FAUTRELLE, Yves; ETAY, Jacqueline; PERRIER,

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a submission under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a submission under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below.
4. ☒ The US has been elected (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. ☒ is attached hereto (required only if not communicated by the International Bureau).
   b. ☐ has been communicated by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
   a. ☒ is attached hereto.
   b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. ☒ are attached hereto (required only if not communicated by the International Bureau).
   b. ☐ have been communicated by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☐ have not been made and will not be made.
8. ☒ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371 (c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ An English language translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11 to 20 below concern document(s) or information included:

11. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A preliminary amendment.
14. ☐ An Application Data Sheet under 37 CFR 1.76.
15. ☐ A substitute specification.
16. ☐ A power of attorney and/or change of address letter.
17. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13*ter*.2 and 37 CFR 1.821 - 1.825.
18. ☐ A second copy of the published International Application under 35 U.S.C. 154(d)(4).
19. ☐ A second copy of the English language translation of the International Application under 35 U.S.C. 154(d)(4).
20. ☒ Other items or information: Requete PCT; PCT/IB/304; PCT/IB/308; WO 03/106009A1; PCT/ISA/220; PCT/ISA/210; PCT/IPEA/401; PCT/IPEA/416; PCT/IPEA/409; Formal Drawings; Patent Practitioners

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U.S. APPLICATION NO. (if known, see 37 CFR 1.5)	INTERNATIONAL APPLICATION NO.	ATTORNEY'S DOCKET NUMBER
unassigned	PCT/FR03/01742	034299-611

21. ☒ The following fees are submitted:					
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06/24	153	10206906	CISCO-6347	8001		$3.00	$28,892.00
06/27	11	11058437	035323-000009	2252		$165.00	$28,727.00
06/27	187	11157319	034914-013	8021		$40.00	$28,687.00
06/27	625	11014218		8021		$40.00	$28,647.00
06/28	26	10949467		9204		-$2,160.00	$30,807.00
06/28	64	10833600	034942-354	1501		$1,400.00	$29,407.00
06/28	65	10833600	034942-354	1504		$300.00	$29,107.00
06/28	66	10833600	034942-354	8001		$3.00	$29,104.00
06/28	148	09798498	IMM1P096A	1801		$790.00	$28,314.00
06/29	1	10807045	035695-003	2202		$50.00	$28,264.00
06/29	2	10807045	035695-003	2201		$300.00	$27,964.00
06/29	32	PCT/US05/22068	IPOL-0008/WO	1601		$300.00	$27,664.00
06/29	33	PCT/US05/22068	IPOL-0008/WO	1704		$2,075.00	$25,589.00
06/29	34	PCT/US05/22068	IPOL-0008/WO	1702		$1,211.00	$24,378.00
06/29	35	PCT/US05/22068	IPOL-0008/WO	1703		$26.00	$24,352.00
06/29	36	PCT/US05/22068	IPOL-0008/WO	8007		$20.00	$24,332.00
06/29	198	11093898	034299-632	1051		$130.00	$24,202.00
06/30	1	PCT/US05/18727	034704-070	8007		-$240.00	$24,442.00
06/30	33	10519615		9204		-$100.00	$24,542.00
06/30	80	PCT/US05/22028	IPOL-0006/WO	1601		$300.00	$24,242.00
06/30	81	PCT/US05/22028	IPOL-0006/WO	1704		$2,075.00	$22,167.00
06/30	82	PCT/US05/22028	IPOL-0006/WO	1702		$1,211.00	$20,956.00
06/30	83	PCT/US05/22028	IPOL-0006/WO	1703		$65.00	$20,891.00
06/30	84	PCT/US05/22028	IPOL-0006/WO	8007		$20.00	$20,871.00
06/30	105	PCT/US05/22146	VUBQ-0001/WO	1601		$300.00	$20,571.00
06/30	106	PCT/US05/22146	VUBQ-0001/WO	1704		$2,075.00	$18,496.00
06/30	107	PCT/US05/22146	VUBQ-0001/WO	1702		$1,211.00	$17,285.00
06/30	108	PCT/US05/22146	VUBQ-0001/WO	1703		$182.00	$17,103.00
06/30	109	PCT/US05/22146	VUBQ-0001/WO	8007		$60.00	$17,043.00

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TRANSMITTAL FORM

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Total Number of Pages in This Submission	39

Application Number	10/517,968
Filing Date	December 13, 2004
First Named Inventor	Roger BOEN
Art Unit	2673
Examiner Name	Unassigned
Attorney Docket Number	034299-611

ENCLOSURES *(check all that apply)*

- ☐ Fee Transmittal Form
  - ☐ Fee Attached
- ☐ Amendment / Reply
  - ☐ After Final
  - ☐ Affidavits/declaration(s)
- ☐ Extension of Time Request
- ☐ Express Abandonment Request
- ☐ Information Disclosure Statement
- ☐ Certified Copy of Priority Document(s)
- ☐ Reply to Missing Parts/ Incomplete Application
  - ☐ Reply to Missing Parts under 37 CFR1.52 or 1.53
- ☐ Drawing(s)
- ☐ Licensing-related Papers
- ☐ Petition
- ☐ Petition to Convert to a Provisional Application
- ☐ Power of Attorney, Revocation Change of Correspondence Address
- ☐ Terminal Disclaimer
- ☒ Request for Refund
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  - ☐ Landscape Table on CD
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- ☐ Appeal Communication to Board of Appeals and Interferences
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- ☐ Proprietary Information
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SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT

Firm	THELEN REID & PRIEST LLP		
Signature	S. Bhat		
Printed Name	Suvashis Bhattacharya		
Date	3/14/06	Reg. No.	46,554

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SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT

Firm	THELEN REID & PRIEST LLP		
Signature	S. Bhat		
Printed Name	Suvashis Bhattacharya		
Date	3/14/06	Reg. No.	46,554

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